

## CLAIMS

1. A laser-beam emitting head for irradiating a portion to be machined with laser beams outputted from a laser unit, said laser-beam emitting head comprising:

an emitting head body having a light guide member for guiding the laser beams;

a converging lens for converging the laser beams guided from the light guide member in the head;

a reflecting mirror for irradiating the portion to be machined with the converged laser beams;

mirror rotating means for rotatively holding the reflecting mirror around the optical axis of the laser beam;

distance-adjustment means for adjusting the relative distance between the reflecting mirror and the converging lens; and

moving means for moving said reflecting mirror and said converging lens with the relative distance being maintained,

wherein said light guide member in the head, said converging lens and said reflecting mirror are inserted to and withdrawn from the portion to be machined in a narrow gap.

2. A laser-beam emitting head according to claim 1,

wherein said emitting head body of the laser-beam emitting head is provided with a flat and elongated elevation support mechanism which is slidable by a frame elevating unit, said elevation support mechanism is provided with an irradiation scan optical system constituted by a converging lens and a reflecting mirror, and said frame elevating unit constitutes moving means for moving said converging lens and said reflecting mirror with the relative distance being maintained.

3. A laser-beam emitting head according to claim 1, wherein said light guide member in the head includes a cylindrical member and an optical member for causing the inside portion of said cylindrical member to be an air state, and said light guide member in the head is joined to the emitting head body of the emitting head such that the laser beams are guided to said converging lens.

4. A laser-beam emitting head according to claim 1, wherein said light guide member in the head is made of glass so as to guide the laser beams to said converging lens.

5. A laser-beam emitting head according to claim 1, wherein an optical path from said light guide member in the head to said converging lens and an optical path from said

converging lens to said reflecting mirror are exposed to an environment and said both optical paths are formed into spatial transmission passages realized by the environment.

6. A preventive-maintenance/repair apparatus for an incore structure including a laser unit for outputting the laser beams, laser beam guiding means for guiding the laser beams output from said laser unit into a nuclear reactor and a laser-beam emitting head for irradiating a portion of an incore structure to be machined with the laser beams guided into the reactor, said preventive-maintenance/repair apparatus for an incore structure comprising:

a body locating unit suspended in said reactor so as to be disposed in a core portion;

a head moving mechanism for moving forward and rearward said laser-beam emitting head accommodated in said body locating unit with respect to the portion to be machined; and

laser-beam transmission means for receiving the laser beams guided into the nuclear reactor so as to guide the laser beam to said laser-beam emitting head,

said laser-beam emitting extending towards the portion on the inner wall of a shroud to be machined.

7. A preventive-maintenance/repair apparatus for an incore structure according to claim 6, wherein said body

locating unit incorporates an elongated cylindrical body case, said laser-beam emitting head and said laser beam transmission means are accommodated in said body case to be introduced therinto and withdrawn therefrom and said body locating unit is suspended through a lattice of an upper lattice plate so as to be disposed on a control-rod guide pipe in an accommodated state.

8. A preventive-maintenance/repair apparatus for an incore structure according to claim 6, wherein said body locating unit incorporates a clamping unit having an upper portion secured to an upper lattice plate, a turning unit for determining a direction in which said laser-beam emitting head accommodated in said body case extends, a head moving mechanism for extending said laser-beam emitting head and said laser beam transmission means to the portion to be machined and a base elevating unit for moving upward and downward a body base for supporting said head moving mechanism in said body case.

9. A preventive-maintenance/repair apparatus for an incore structure according to claim 6, wherein said laser beam transmission means constitutes a movable transmission passage for receiving the laser beams in a water environment in said nuclear reactor to transmit the laser beams to said laser-beam emitting head in air.

10. A light transmission apparatus including light transmission means constituting a light transmission passage by combining mirrors and a mirror adjustment unit for controlling an angle of inclination of at least one of mirrors constituting said light transmission means, said light transmission apparatus comprising:

electronic optical image pickup means disposed coaxially with an optical axis of light which is transmitted in said light transmission passage;

an image processing unit for calculating image information supplied from said electronic optical image pickup means to measure an amount of deviation of the angle of said mirror from a normal position; and

a control unit for receiving the amount of deviation of the angle of said mirror so as to operate said mirror adjustment unit.

11. A light transmission apparatus according to claim 10, wherein said light transmission means incorporates targets for an image process disposed adjacent to said mirrors and said targets have light transmission openings.

12. A light transmission apparatus according to claim 10 or 11, wherein said light transmission means incorporates an illuminating unit for illuminating

portions adjacent to said targets for the image process.

13. A light transmission apparatus according to claim 10, wherein said image processing unit includes a pattern matching unit which compares a previously registered image pattern with an image photographed at a time when said mirror is adjusted with each other so as to detect an amount of deviation in the position of the photographed image.

14. A light transmission apparatus including light transmission means for constituting a light transmission passage by combining mirrors and a mirror adjustment unit for controlling an angle of inclination of said mirrors constituting said light transmission means, said light transmission apparatus comprising:

half mirrors or wavelength separation mirrors which constitute a portion of said mirrors on said light transmission passage;

a light-position detecting unit disposed on a sampling optical path to which light separated by said half mirrors or said wavelength separation mirrors is transmitted; and

a control unit for calculating information about deviation in the light position output from said light-position detecting unit to operate a mirror

adjustment unit in a direction in which an amount of deviation in the light position is canceled.

15. A light transmission apparatus according to claim 14, wherein one or more types of guide laser beam units for making incident guide laser beams on said light transmission passage are provided.

16. A light transmission apparatus including light transmission means for constituting a light transmission passage by combining mirrors and a mirror adjustment unit for controlling an angle of inclination of at least one mirror constituting said light transmission means, said light transmission apparatus comprising:

a main laser unit for outputting laser beams for machining, inspecting or preventive-maintenance/repair of a portion to be machined;

a guide laser unit for outputting a guide laser beam which is different from the main laser beam;

half mirror guide means for guiding the guide laser beam emitted from said guide laser beam nit to said light transmission passage;

sampling separation mirror means disposed at an intermediate position of said light transmission passage;

parallel reflecting optical means disposed on an optical path separated by said separation mirror means;

a light position detecting unit on which light reflected by said parallel reflecting optical is made incident through said half mirror guide means; and

a control unit for receiving information about position deviation of light detected by said light position detecting unit to process information so as to operate said mirror adjustment unit.

17. A light transmission apparatus including light transmission means for constituting a light transmission passage by combining mirrors and a mirror adjustment unit for controlling an angle of inclination of at least one mirror constituting said light transmission passage, said light transmission apparatus comprising:

a main laser unit for outputting laser beams for machining, inspecting or preventive-maintenance/repair of a portion to be machined;

a guide laser unit for outputting a non-polarized or circularly polarized guide laser beam which is different from the main laser beam;

half mirror guide means for guiding the guide laser beam outputted from said guide laser beam unit to said light transmission passage;

sampling separation mirror means disposed in two portions different in a direction of an optical axis on said light transmission passage;



parallel reflecting optical means provided for optical paths separated by said sampling separation mirror means;

polarizing optical means provided for either of the separated optical paths of said two parallel reflecting optical means;

separation polarizing optical means to which light reflected by each of said parallel reflecting optical means through said half mirror guide means;

first and second light position detecting units to which each reflected light separated by said separation parallel optical means is supplied; and

a control unit for receiving information about deviation in the light position detected by said two light position detecting units to process information so as to operate said mirror adjustment unit.

18. A light transmission apparatus including light transmission means for constituting a light transmission passage by combining mirrors and a mirror adjustment unit for controlling an angle of inclination of at least one mirror constituting said light transmission passage, said light transmission apparatus comprising:

a main laser unit for outputting laser beams for machining, inspecting or preventive-maintenance/repair of a portion to be machined;

a plurality of guide laser units for outputting guide laser beams having the wavelengths which are different from that of the main laser beam and oscillation wavelengths which are different from one another;

a plurality wavelength separation mirror means disposed on said light transmission passage to correspond to said guide laser units;

parallel reflecting optical means disposed on optical paths for the guide laser beams separated by said wavelength separation mirror means;

wavelength separation mirror means for reflected light to separate the guide laser beams reflected by each of said parallel reflecting optical means for each wavelength to guide the guide laser beams;

a plurality of light position detecting units for individually receiving reflected guide laser beams separated by said wavelength separation mirror means; and

a control unit for receiving information about deviation in the light position detected by each of said light position detecting unit to process information so as to operate said mirror adjustment unit.

19. A method of adjusting a light transmission apparatus comprising the steps of:

providing electronic optical image pickup means on an extension line of an optical axis of a light

transmission passage formed by combining mirrors adjacent to a light source;

causing said electronic optical image pickup means to observe a mirror image of a target for an image process through a first automatic adjustment mirror adjacent to the light source;

adjusting said first automatic adjustment mirror such that the observed mirror image is positioned in the central portion; and

adjusting the optical axis of said light transmission passage by sequentially adjusting automatic adjustment mirrors in a similar mirror adjustment method after said first automatic adjustment mirror has been adjusted.

20. A method of adjusting a light transmission apparatus comprising the steps of:

disposing a light-position detecting unit on an extension line of a light transmission passage formed by combining mirrors adjacent to a light source;

disposing a parallel reflecting optical means at an intermediate position of said light transmission passage or adjacent to a laser-beam emitting head;

causing said light position detecting unit to detect light reflected by said parallel reflecting optical means for the guide laser beam made incident from the light

transmission passage adjacent to the light source; and

performing feedback-control adjustment of an angle of an automatic adjustment mirror so as to cancel an amount of deviation in the light position detected by said light position detecting unit.

21. A method of adjusting a light transmission apparatus comprising the steps of:

disposing electronic optical image pickup means on an extension line of a light transmission passage formed by combining mirrors adjacent to a light source;

causing said electronic optical image pickup means to observe a mirror image of a target for an image process through a first automatic adjustment mirror adjacent to the light source;

adjusting said first automatic adjustment mirror such that the observed mirror image is positioned in the central portion of the image;

performing coarse adjustment of the light transmission passage by sequentially adjusting the automatic adjustment mirrors on the light transmission passage by a similar method to the method of adjusting said first automatic adjustment mirror after said first automatic adjustment mirror has been adjusted; and

performing a precise adjustment of the light transmission passage by using a light position detecting

unit disposed on an extension line of said light transmission passage adjacent to a light source and parallel reflecting optical means disposed at an intermediate position of said light transmission passage or adjacent to a laser-beam emitting head,

wherein said precise adjustment operation is performed such that a light position detecting unit detects reflected light of the guide laser beam made incident from the light source of the light transmission passage and reflected by said parallel reflecting optical means and adjustment of the angle of said automatic adjustment mirror is feedback-controlled such that an amount of deviation in the light position detected by said light position detecting unit is canceled so as to correct precise adjustment of said light transmission passage is performed and an influence of external vibration.

22. A preventive-maintenance/repair apparatus for an incore structure comprising:

a laser oscillator;

a turning vehicle having a turning function with which rotation is permitted around substantially the central portion in a reactor pressure vessel;

a horizontal light guide pipe mounted on said turning vehicle;

at least one light guide pipe structured to

establish the connection between an end of said horizontal light guide pipe and a laser emission opening of said laser oscillator;

at least one reflecting mirror box arranged to establish the connection between said light guide pipe and said horizontal light guide pipe or between said light guide pipes and having an alignment function for modifying a reflection angle; and

a laser machining unit connected to said horizontal light guide pipe,

wherein one portion or an overall portion, of a portion in which said light guide pipe and said reflecting mirror box are connected to each other and a portion in which said horizontal light guide pipe and said laser machining unit are connected to each other, is partitioned by transparent members.

23. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein an end surface of each joint portion of said horizontal light guide pipe and an end surface of each of said light guide pipes of said laser machining unit mounted on said turning vehicle is partitioned by a flat glass to maintain a closed space and at least one water nozzle is secured to spray a liquid surface side of said flat glass.

24. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein an end surface of each joint portion of said light guide pipe mast, said horizontal light guide pipe and said laser machining unit are partitioned by flat glasses from each other to maintain a closed space, an air pressure tube is connected to each joint portion, and an end of said air pressure tube is connected to a dry air source, a nitrogen gas source or an inert gas source.

25. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein said turning vehicle includes a turning-vehicle clamping mechanism having a link, a hydraulic piston and a pad; a turning mechanism including a rotational bearing with said turning-vehicle clamping mechanism as a base and permitting rotation of the overall body of said turning vehicle around the center of the reactor pressure vessel, a motor for turning and wheels for turning; and a horizontal light guide pipe disposed on said turning mechanism and having a slide mechanism incorporating a linear guide, a ball screw, gears and a servo motor.

26. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein said laser machining unit includes a connection mechanism to be

detachable with respect to a horizontal light guide pipe included in said turning vehicle; a light guide pipe for transmitting the laser beam transmitted from said horizontal light guide pipe perpendicularly connected downwards such that said connection mechanism serves as a base, a laser emitting head disposed at the leading end of said light guide pipe; and a fixing portion for fixing, to the center of the axis, said laser emitting head at an arbitrary height of a jet pump diffuser disposed in said reactor pressure vessel.

27. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein said laser machining unit incorporates a connection mechanism to be detachable with respect to a horizontal light guide pipe mounted on said turning vehicle; a rotational light guide pipe for transmitting the laser beam transmitted from said horizontal light guide pipe perpendicularly connected downward such that said connection mechanism serves as a base and having a shape and dimensions with which seating on the upper end of said diffuser is permitted; a connection portion for a machining arm included in the lower end portion of said rotational light guide pipe, said connection portion being detachable from a remote position; and a machining arm arranged to be detachable with respect to said connection portion in said reactor pressure vessel



from a remote position to perform a laser irradiation operation of the outer surface of said diffuser.

28. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein said laser machining unit includes a connection mechanism to be detachable with respect to said horizontal light guide pipe included in said turning vehicle; a light guide pipe mast perpendicularly connected downwards such that said connection mechanism serves as a base; a shroud-intermediate portion diffraction mechanism having a hydraulic piston and a parallel link mechanism; an insertion mast having a shape with which passing through a space between said jet pump and the outer wall of said shroud body is permitted; and a laser emitting head.

29. A preventive-maintenance/repair apparatus for an incore structure according to claim 26 or 28, wherein said laser emitting head includes a converging lens unit, a reflecting mirror or a prism for scanning, a horizontal scanning mechanism, a swinging scan mechanism, a step translation mechanism, a focal-distance adjustment mechanism, a dust removing unit from a surface which must be machined, at least one small microphone, a half mirror, a retro-reflector and a monitoring camera, the structure of the optical system of said laser emitting head is formed

such that the laser beam transmitted from said light guide pipe connected to said head is passed through a bellows pipe to be introduced into said half mirror after which the laser beam is divided by said half mirror to said retro-reflector and said converging lens, the laser beam transmitted to said retro-reflector is polarized by a polarizing filter and returned to said half mirror and then to said laser oscillator, the laser beam transmitted to said converging lens is passed through a bellows pipe and a converging lens and then passed through the partitioning flat glass, after which the laser beam is introduced into water and then reflected by said reflecting mirror for scanning so as to be applied to the portion to be machined, a drive mechanism of said laser emitting head includes said step translation mechanism which moves the overall body of the optical system of said head in a stepped manner and which includes a linear guide, a ball screw, gears and a rotation actuator, a converging lens unit for changing the focal distance from a remote position and including gears, screws and a rotation actuator, a swinging scan mechanism which enables said reflecting mirror to swing and rotate around the optical axis of the incident laser beam and which includes a bearing, gears and a rotation actuator and a horizontal scan mechanism which enables the overall bodies of said converging lens unit and said swinging scan mechanism to be moved laterally in a

stepped manner and which includes a liner guide, a ball screw, gears and rotation actuator.

30. A preventive-maintenance/repair apparatus for an incore structure according to claim 26 or 28, wherein said laser emitting head includes light converging lens unit, a reflecting mirror or a prism for scanning, a swinging scan mechanism, a telescopic light guide pipe mechanism, a focal-distance adjustment mechanism, a dust removing unit from a surface to be machined, at least one small microphone and a monitoring camera, the structure of the optical system of said laser emitting head is formed such that the laser beam transmitted from said light guide pipe to which said head is connected is passed through a hollow-piston type telescopic light guide pipe mechanism partitioned by two flat glass plates so as to be introduced into said converging lens unit, passed through said partitioning flat glass, introduced into water and reflected by said reflecting mirror for scanning so as to be applied to the portion to be machined, and the drive mechanism of said laser emitting head includes said telescopic light guide pipe mechanism which enables the overall body of the optical system of said head to be vertically extended/contracted in a stepped manner and which includes two flat glass plates, a linear position sensor, an O-ring, a piston mechanism, a returning spring

and an air pressure tube, a converging lens unit which has a focal distance changed from a remote position and which includes gears, screws and a rotation actuator and a swinging scan mechanism which enables said reflecting mirror to be swung and rotate perpendicularly to the optical axis of the incident laser beam and in a direction of the axis including the mirror surface and which incorporates a bearing, a rotation actuator and an angle detecting sensor.

31. A preventive-maintenance/repair apparatus for an incore structure according to claim 26 or 28, wherein said laser emitting head includes a converging lens unit, a converging lens rotating mechanism, a reflecting mirror or a prism for scanning, a telescopic light guide pipe mechanism, a focal-distance adjustment mechanism, a swinging scan mechanism, a dust removing unit from a surface to be machined, at least one small microphone and a monitoring camera, the structure of the optical system of said laser emitting head is formed such that the laser beam emitted from said light guide pipe to which said head is connected is passed through a hollow piston shape telescopic light guide pipe mechanism partitioned by two flat glass plates, introduced into said converging lens unit formed and assembled such that the position of the focal point is polarized side by somewhat shifting the

optical axis of said converging lens with respect to a light incident axis, passed through said partitioning flat glass, introduced into water and reflected by said reflecting mirror for scanning so that the portion to be machined is irradiated with the laser beam, the drive mechanism of said laser emitting head incorporates said telescopic light guide pipe mechanism which enables the overall body of the optical system of said head to be extended/contracted vertically in a stepped manner and which includes two flat glass plates, a linear position sensor, an O-ring, a piston mechanism, a returning spring and an air pressure tube, a converging lens unit which has a focal distance which is changed from a remote position and which has a focal-distance adjustment mechanism including gears, screws and a rotation actuator, a converging-lens rotating mechanism which rotates the overall body of said converging lens unit around the optical axis of the laser beam and which includes gears, screws and a rotation actuator and a swinging scan mechanism rotating said reflecting mirror coaxially with the rotational axis of said converging-lens rotating mechanism and including a rotational shaft and a rotation actuator.

32. A preventive-maintenance/repair apparatus for an incore structure according to claim 22, wherein said laser

machining unit includes an underwater propeller composed of a screw and a motor and disposed adjacent to the leading end of said laser machining unit, and the propelling force of said underwater propeller prevents external force exerted on said laser machining unit and reaction of a water flow or said dust removing unit from the surface to be machined so as to obtain force for stably maintaining said laser emitting head in the portion to be machined.

33. A preventive-maintenance/repair apparatus for an incore structure comprising:

a laser oscillator enclosed in a pressure-proof container;

a reflecting mirror box having an angle-modifying alignment mechanism connected to said pressure-proof container and composed of at least one mirror;

a horizontal light guide pipe connected to said reflecting mirror box;

a turning vehicle on which said horizontal light guide pipe is mounted and which has a function of turning around substantially the central portion in said reactor pressure vessel; and

a laser machining unit connected to said horizontal light guide pipe,

wherein a portion in which said horizontal light guide pipe and said laser machining unit are connected to

each other is partitioned by a transparent member.

34. A preventive-maintenance/repair apparatus for an incore structure according to claim 33, wherein said laser oscillator has a positioning mechanism to be mounted on said turning vehicle, assembled and separated and a portion in which said laser oscillator and said reflecting mirror box are connected to each other is partitioned by a transparent member.